CAI335 SOLAR AND WIND ENERGY SYSTEM

UNIT V NOTES

5.1 Ocean Energy

Ocean energy refers to all forms of renewable energy derived from the sea. There are three main types of ocean technology: wave, tidal and ocean thermal. All forms of energy from the ocean are still at an early stage of commercialisation.

5.1.1 ocean Energy sources.

1. Ocean tidal energy. It refers to the hydroenergy in ocean tides. Ocean tides occur due to gravitational attractive forces from sun and moon. The level of the ocean water rises periodically during high tides and drops during low tides. The difference in head of water during high tide and low tide is used for rotating hydro turbine enerator units installed within barrages (dams) to obtain electrical energy.

2. Ocean wave energy. It refers to the waves of water from ocean to the shore. Ocean waves occur due to rotation of earth and the winds over ocean surface. Waves have an interval of 4 to 12 seconds and crest of a few centimetres to about 10 m. Locations having waves with crest height of 3 m and above have higher energy density.

Ocean wave machines are installed on floating power plants or **on-shore power plants.** The rotor of the wave machine is rotated by wave energy. Wave machine drives generator rotor or pumps water to the reservoir at higher level.

3.Ocean thermal energy. It refers to the thermal energy acquired by the ocean waterfrom solar radiation. The warm water from upper levels of ocean (at about 25°C) is pumped through heat exchangers. Thermal energy is extracted and converted to electrical energy by steam turbine-generator or vapour turbine-generator. Cold water from the bottom of the sea (at about 10°C) is used for condenser.

Ocean current energy. Energy from ocean currents refers to hydro-energy in water currents through the large rivers terminating in the ocean. The currents have kinetic energy which is converted into electrical energy by turbine generators.

Ocean wind energy refers to **off-shore wind energy** resources over oceans.

Ocean biomass energy refers to organic matter from oceans e.g. aquatic vegetation, algae and animals. Rapidly growing varieties of ocean algae, ocean kelp are harvested periodically. The ocean biomass may be converted

into methane rich biogas by wet anaerobic digestion process. Alternatively, biomass may be dried and burnt.

4. **Hydroelectric energy.** The hydrogical cycle results in rainfall, which causes river flows that can be trapped behind dam to even out the variations in the river flows and thus become source of either low-head or high-head (dam) hydroelectric energy. Small scale hydroelectric facilities can supply in principle significant amounts of electricity for irrigation or portable water pumping, lighting, health and educational purposes. The total amount of such a resource is very poorly documented but apt to be large.

5.2 OTEC principles

5.2.1 Working Principle of Ocean Thermal Energy Conversion (OTEC)

The principle of OTEC is that "there is a temperature difference between water at the bottom of the sea and water at the top", this temperature difference can be used to operate a heat engine.Most of the radiation is being absorbed at the surface layer of water. The mixing between hot and cold water is prevented because no thermal convection occurs between hot and cold water layers. This means that the surface layer will act as a "source" and cold layers act as a "sink". Therefore, it is essential to connect the reversible heat engines between source and cold sink to produce work, that can be converted into required applications.

5.2.2 Types of OTEC Plants

The plants which employ carnot-type process to generate power between the two steady temperatures are called. **Ocean Thermal Energy Conversion (OTEC) plants.**

The two basic types of OTEC systems:

1. Closed cycle (or Anderson cycle) system.

2. Open cycle (or Claude cycle) system.

Closed cycle (Anderson cycle, vapour cycle) system

All the systems being proposed for construction, now work on "Closed Rankine cycle' (Anderson cycle, vapour cycle) and use low boiling point working fluids like ammonia,propane, freon (R-12, R-22) etc. These systems will be located off-sore on large floating platforms or inside floating hulls.The warm surface water is used for supplying the heat input in the 'boiler', while cold water brought up from ocean depths is used for extracting the heat in the 'condenser'.

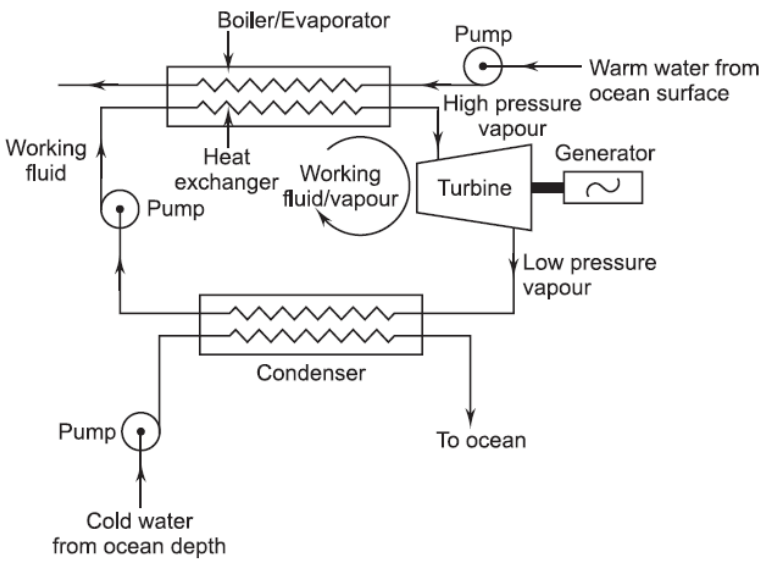


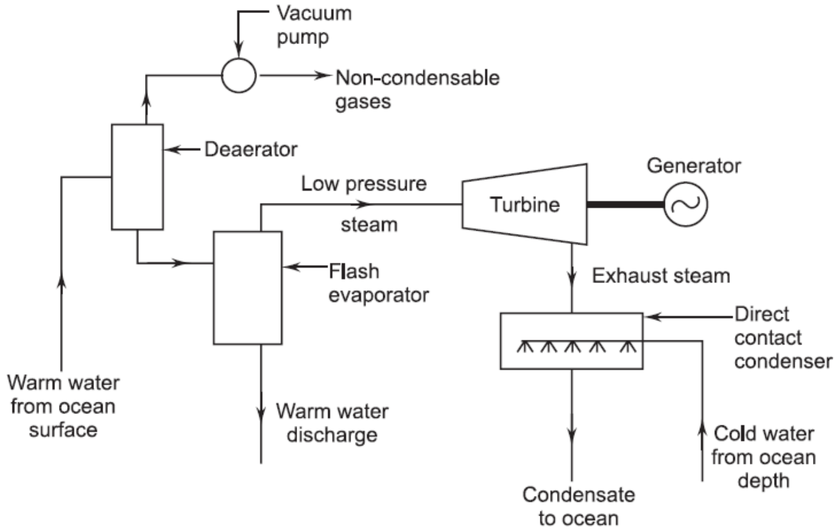
Figure: Schematic layout of the closed or Anderson cycle OTEC plant.

Working:

- Warm water from ocean surface is circulated through a pump to a ‘heat exchanger’which acts as a ‘boiler’ to generate working fluid ammonia vaour at high pressure.
- This vapour expands in the ‘turbine’ to develop mechanical power, which in turn runs an electric ‘generator’ to produce electric power.
- The working vapour from turbine at low pressure is condensed in the ‘condenser’with the help of cold water drawn from the depth of ocean through a pump.
- The “**major advantage”** of this system is that fluid evaporates at around 25°C and does not require vacuum pumps. The pressure at the turbine will be of the order of 9 to 6 bar resulting in compact turbines.
- “Ammonia” has better operating characteristics than propane and it is much less inflammable. On the other hand ammonia forms irritating vapour and probably could not be used with copper heat exchanger.
- “Propane” is compatible with most heat-exchanger materials, but is highly flammable and forms an explosive mixture with air.
- Ammonia has been used as the working fluid in successful tests of the OTEC
- concept with closed cycle systems.
- Because of the low cycle efficiency the heat to be transferred in the boiler and condenser is large. In addition, the temperature difference between the sea water and the working fluid in these heat exchangers has to be restricted to very small values. For these reasons, very high flow rates are required for the sea water both in theboiler/evaporator and the condenser. This results in high pumping power requirements and is reflected in the gross power outputs which are 20-50 percent higher than net power outputs.

Open cycle (Claude cycle, steam cycle) system

In this system, the warm water is converted into *'steam'* in an evaporator. The steam drives steam-turbine generator to deliver electrical energy.



Working:

- The warm water from ocean surface is admitted through a *'deaerator'* to the *'flash evaporator'* which is maintained under *high vacuum*. As a result, *low pressure steamis generated* due to *throttling effect* and the remainder warm water is discharged back to the ocean at high depth.
- The deaerator also removes the dissolved non-condensable gases from water before supplied to the evaporate.
- The low pressure steam having very high specific volume is supplied to *'turbine'*where it expands and the mechanical power so developed is converted into electric power by the *'generator'*.
- The exhaust steam, from turbine is discharged into a direct contact type condenser where it mixes with cold water drawn from ocean at a depth of about 1 to 2 km. The mixture of condensed steam and ocean cold water are discharged into the ocean.

Advantages:

1. The warm ocean water is flash evaporated and the need for having a surface heat exchanger is eliminated.

2. The portable water is obtained when the exhaust steam from the turbine is condensed.

Disadvantages:

1. As the steam is generated at very low pressure (0.02 bar approx.) the volume of steam to be handled is very large, leading to a very large diameter for the steam turbine.

2. To maintain the vacuum in the flash evaporator, massive vacuum pumps will be required.

3. The plant cost is high.

4. The plant is subjected to extremely reverse stresses

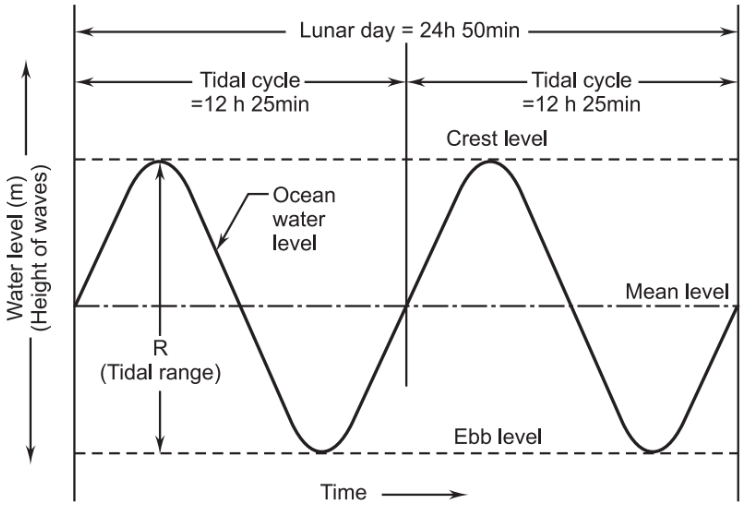
5.3 Tidal Energy

The periodic rise and fall of the water level of sea which are carried by the action of the sun and moon on water of the earth is called the ‘tide’. The daily variation in tidal level is mainly due to the changing position of the moon.

- Tidal energy can furnish a significant portion of all such energies which are renewable in nature. The large scale up and down movement of sea water represents an unlimited source of energy. If some part of this vast energy can be converted into electrical energy, it would be an important source of hydropower.
- The main feature of the tidal cycle is the difference in water surface elevations at the high tide and at the low tide. If this differential head could be utilized in operating a hydraulic turbine, the tidal energy could be converted into electrical energy by means of an attached generator

5.3.1 Tidal Range (R)

The tidal range is the difference between consecutive high tide and low tide water level. It is denoted by R and is measured in metres. Tidal energy refers to the potential energy in the tidal range.



Tidal range (amplitude) varies widely depending upon geographical location, contour of ocean bed, depth of oceans, distance from coasts etc. It is insignificant in the middle of ocean and significant near coast. Tidal ranges of 0.25 m to 17 m have been recorded in different locations.

5.3.2 Origin of Tides (Tidal Phenomenon)

The tidal energy is due to the gravitational force of attraction between the earth and sun and between earth and moon.

The moon revolves around the earth with a period of 24 hours 50 minutes per one revolution. The earth’s surface facing the moon experiences greater attractive force than the surface away from the moon. Thus ocean water on the moon side experiences a swell (hide tide) and the other side experiences low tide. Such daily tides are called the diurnal tides.

The relative positions of the sun, the moon and the earth have hourly variation, daily variation. Hence tides are affected by these relative positions. Spring tides and Neap tides are caused by relative positions of the moon and the sun with respect to the position of ocean on the earth surface.

8.3.3 Estimation of Energy Potential For a Tidal Power Project

To utilise tidal energy, water must be trapped at high side behind a dam or barrage and then made to drive turbine as it returns to sea during low side. The available energy is proportional to the square of the amplitude of tide. As such the available energy tends to be concentrated around regions of high side. The amount of generation depends only on the tidal phenomenon and can be predicted fairly accurately.

Because of the variations in tidal pattern, the power output shows some variations as under: 1. Two bursts of generation activity per day, beginning about 3 hours before high tide and lasting from 4 to 6 hours.

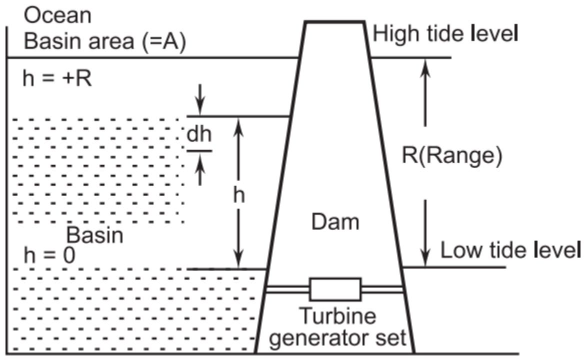
2. The power output in each tidal cycle will increase with the difference between high and low tides. Thus the power output curve will display a 14 day cycle.

3. The high tide time shifts by about one hour every day and the power output will show a similar shift.

4. Spring tide high water always occurs at the same time. Thus the maximum availability will not be disturbed evenly during the day.

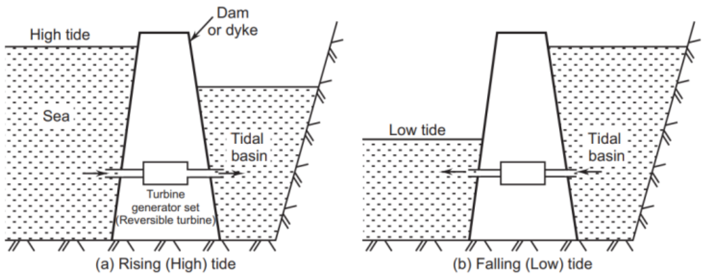
8.3.4 Tidal Energy conversionin a single-basin single-effect/cycle scheme

A single basin scheme is cheaper. However it is not very useful due to the above mentioned reasons in power output. This scheme produces power output, which follows phases of sun and moon and not the load demand of the system. Therefore, a single basin tidal power scheme would always need a standby plant.



8.3.5 Tidal Energy conversion in a single-basin double-effect/cycle scheme

In this system energy is converted into electrical energy during flood tide (rising tide) when the basin is filled and also during the ebb tide (falling tide) when the basin is emptied. Since water flows through the turbine during rising and falling tides in apposite directions, therefore, a reversible turbine is used, which acts as a turbine for either direction of flow.



8.3.6 Components of a Tidal Power Plant

A tidal power plant consists of the following three components: 1. Dam or dyke (low wall); 2. Sluice ways; 3. Power house.

1. Dam or dyke (barrage).

The function of dam or dyke is to form a barrier between the sea and the basin or between one basin and the other in case of multiple basin schemes. It should be constructed by the material available at site or from a nearby place. As the barrage has to withstand the force of sea waves, so the design should be suitable to the site conditions and to economic aspect of development. The crest and slopes of the barrage should be armoured for protection against waves.

2.Sluice ways.

These are used to fill the basin during the high tide or 'empty' the basin during the low tide, as per operational requirement. These devices are controlled through gates.

There are two types of sluice ways: (i) Crest gates: These are more prone to damage by wave action and masses carried by the flow. (ii) Submerged gates with venturi type: Vertical gates are the natural choice and can be fabricated from stainless steel.

3.Power house.

A power house has turbines, electric generators and other auxiliary equipment. As far as possible, the power house and sluice ways should be in alignment with the dam or dyke. According to the suitability, for low heads the following turbines may be used; (i) Bulb turbine; (ii) Tube turbine, and (iii) Straight flow rim type turbine.

8.3.7 High and low tides

High tides: The rise of ocean water in coastal areas is called high tides.

Low tides: The fall of ocean water in coastal areas is called low tides.